Code 567 Wideband Downlink Technologies

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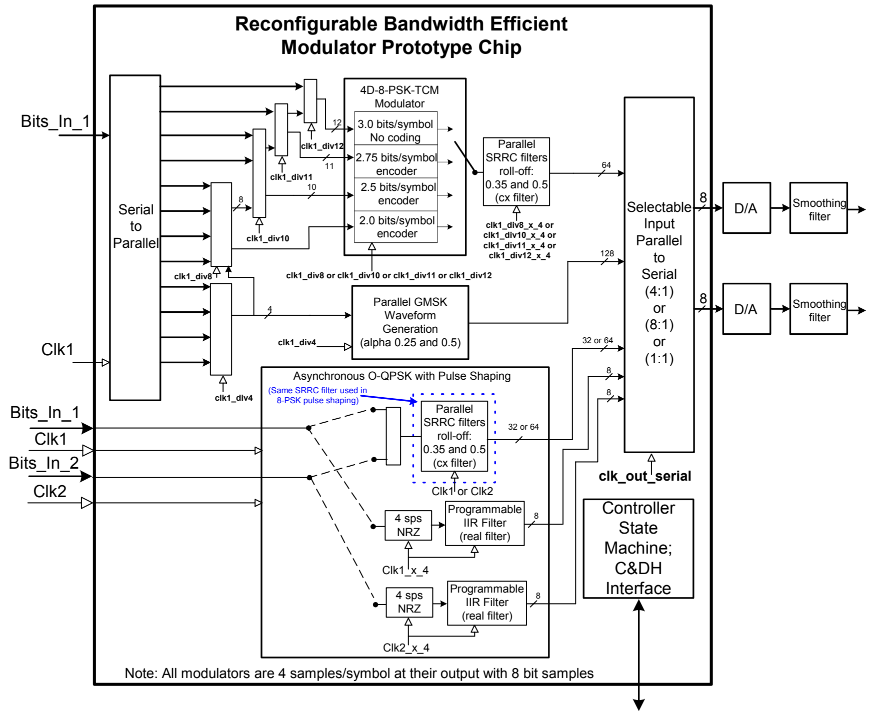
NASA / GSFC Code 567 Wideband Downlink Technologies

- A number of Code 567 technology development activities have been initiated to increase the available downlink data rates for future NASA missions.
- Generic Communications Technology Developments include:
  - Flight Baseband Multi-Modulator ASIC
  - Low Density Parity Check Codes ASIC
  - High Data Rate Parallel Digital Receiver
  - Dual PN Code Usage on TDRSS
- X-Band technology developments include a Phased Array Antenna
- Ka-Band technology developments include:
  - Ka-Band Phased Array Antenna
  - Ka-Band Transition Program for the Space Network and Ground Network
  - Fourth Generation TDRSS User Transponder with compatible Ku/Ka Upconverter
  - Ka-Band downlink for the Solar Dynamics Observatory
- Leading a Laser Communications experiment for the FY09 Mars Telesat

Flight Baseband Multi-Modulator ASIC

Features:

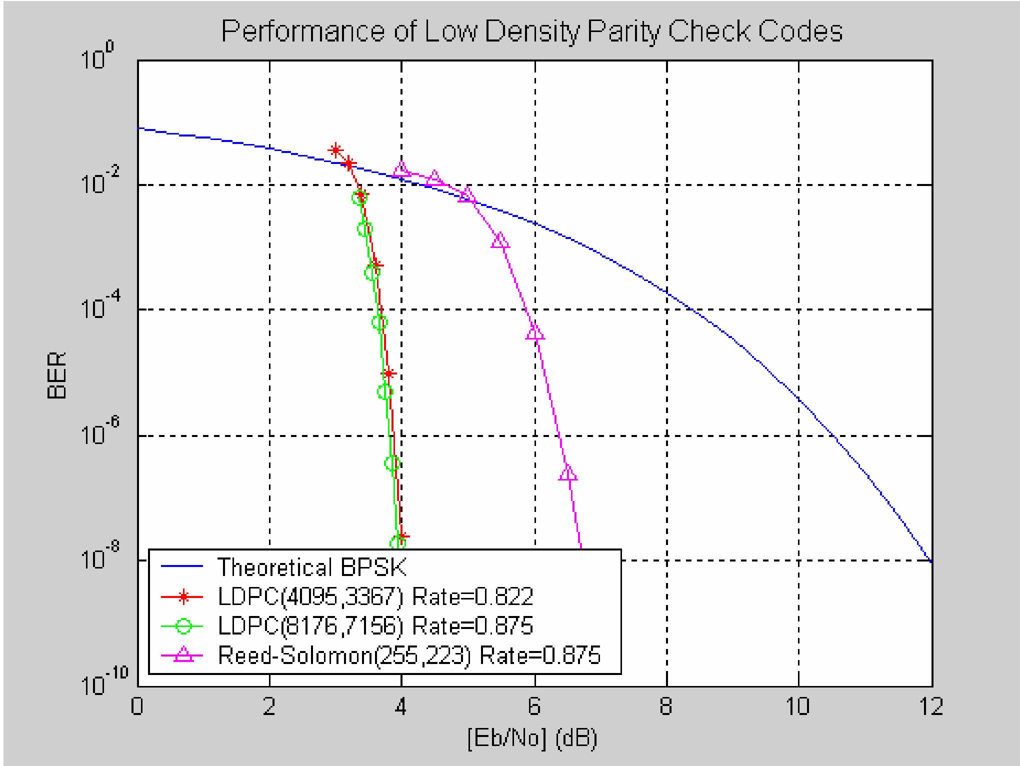
- ❑ **Filtered OQPSK, GMSK, 8-PSK TCM CCSDS Bandwidth Efficient Modulation Schemes.**
- ❑ **Selectable Modulation Schemes (can be changed in Flight if designed to do so).**
- ❑ **Bandwidth efficiency can range from 2.0, 2.25, 2.5, 2.75 and 3.0 Bits/Symbol/Hz.**
- ❑ **Generic FIR Filter implementation.**
  - **User can tailor baseband modulation filter.**
  - **Table of predefined Filter coefficients are available to select among predefined CCSDS Filters.**
- ❑ **Architecture supports serial and parallel inputs.**
- ❑ **Should allow greater than 600 Mbps throughput**



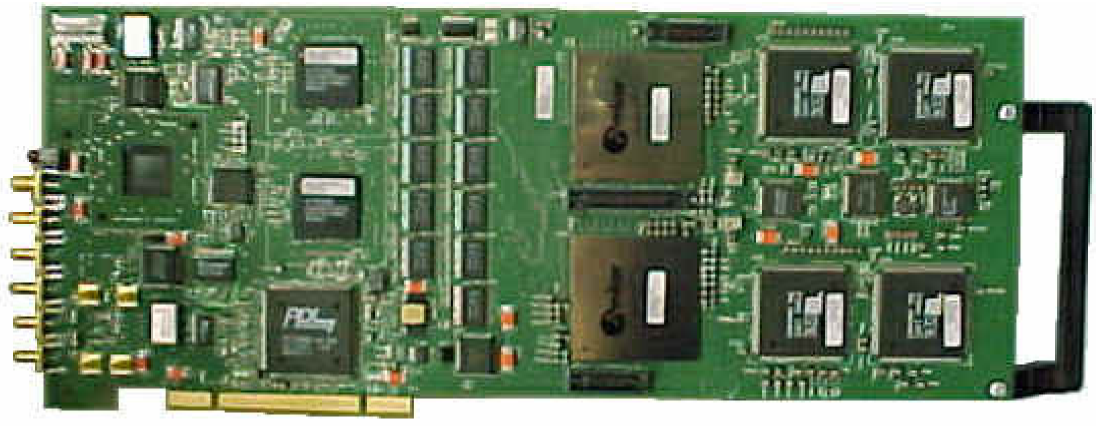
Low Density Parity Check Codes ASIC

Flight Encoder ASIC and Decoder ASIC Features:

- ❑ Near Shannon Capacity performance
  - About 1 dB away from the Shannon Limit @ 10^{-5} BER
  - Very high minimum distance, as much as d_{min}=66
  - No error floor above 10^{-10} BER
  - Outperform Reed-Solomon(255, 223) by 2.5 dB @ 10^{-5} BER
- ❑ High Rate Encoding
  - Code Rate = 0.822 or 0.875
- ❑ Very Simple Encoder Structure
  - Cyclic Encoder (Serial division)
  - Very High Speed
  - Low power (low gate counts)
- ❑ Fast Decoder
  - Highly parallel architecture
  - Very fast iterative convergence
  - Regular structure (one basic processing unit is replicated)



High Data Rate Parallel Digital Receiver



- Demodulates and bit synchronizes BPSK and QPSK (regular or staggered)
- Supports balanced and unbalanced power between I and Q channel
- 100 Kilo-bits per second to 300 Mega-symbols per second per channel (600 Mbps QPSK)
- Tracks dynamic carrier phase and symbol timing with Doppler rates up to 1% of the date rate
- Produces 10 bit soft symbols or one bit hard decision
- Implementation loss less than 2 dB
- Input: Down converted analog signal at bandwidths up to 300 MHz
- Operates in a PCI slot of a standard personal computer

Dual PN Usage on TDRSS

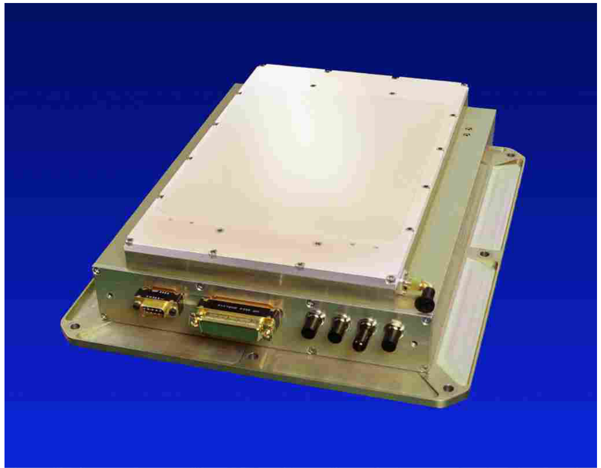
- Allows more data throughput then generally possible thru TDRSS Multiple Access service.
  - “Normal” TDRSS MAR service provides a maximum of 300 Kbps
  - Multiple MAR services can co-exist in the same spectrum
- Developed effective model for the Global Precipitation Measurement Satellite’s communications link.
- Currently Studying TDRSS PN code space for optimal combinations of code selection and phase relationships.
- Performed laboratory tests.

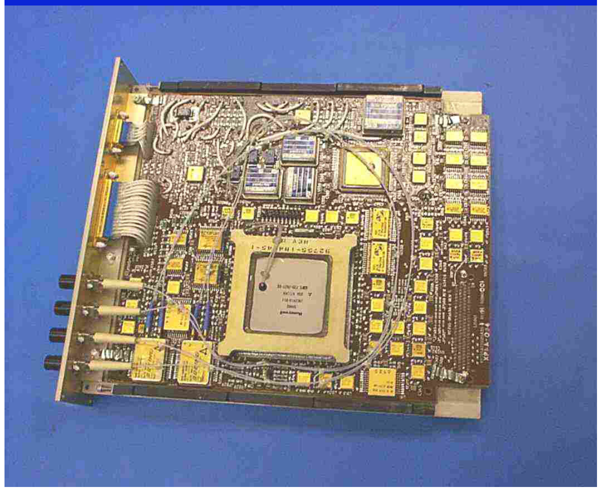
X-Band Phased Array Antenna

Flown on EO-1

Characteristics:

Weight:	**5.5 kg**
Envelope:	**25 x 36 x 15 cm**
Prime Power:	**45 W**
EIRP:	**> 22 dBW at all scan angles**
Frequency:	**8.225 GHz**
Bandwidth:	**400 MHz**
Data Rate:	**105 Mbps**
Scan Angle:	**± 60 deg**
Temperature:	**0 to 40° C**
Command Interface:	**Mil Std 1773 Fiber Optic**





Developed by Boeing in Seattle, WA
64 elements @ 45 mW/element
Integral beamsteering controller (Litton RSN)
Space qualified: radiation, shock, vibration
Launched November 2000
Downloading ~200 Gbit/day

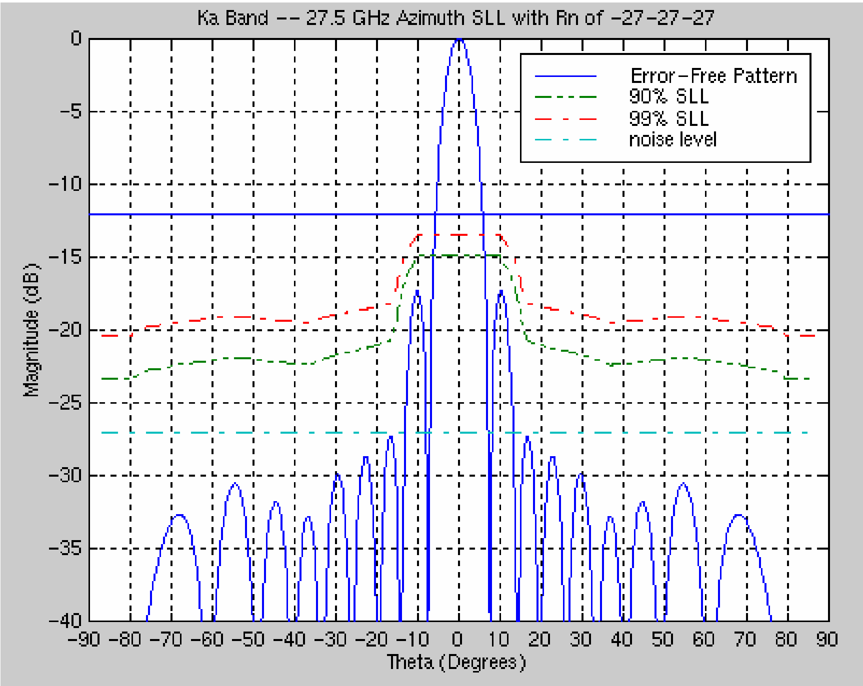
Ka-Band Technology Developments in Code 567

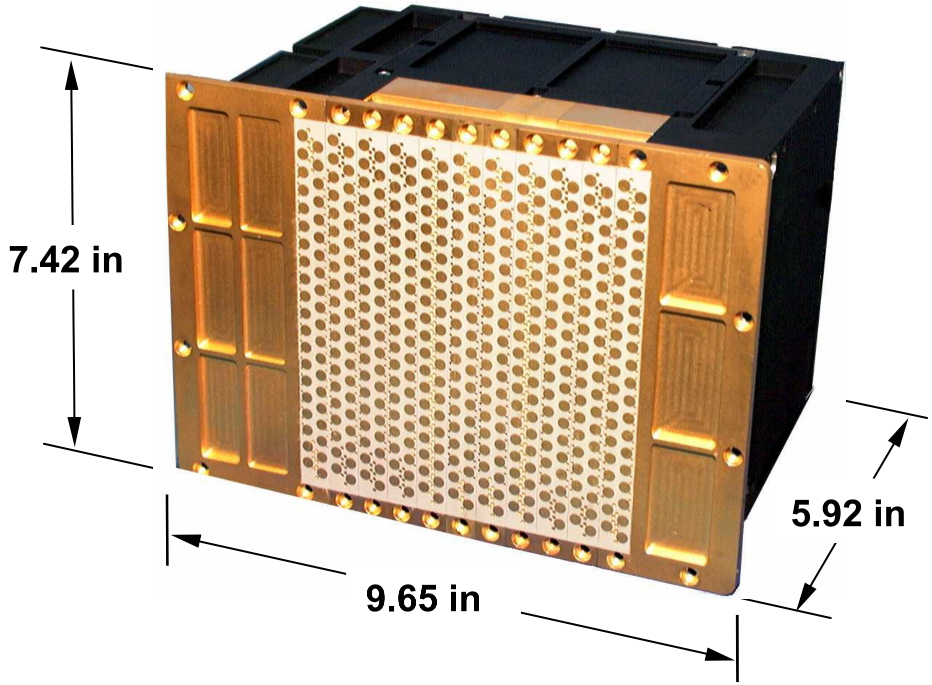
Ka-Band Phased Array Antenna

- The High Rate User Phased Array Antenna (HRUPAA) is a transmit only Ka-Band Phased Array Antenna developed for transmitting data from a low earth orbiting spacecraft to either a ground station or TDRS H,I,J.
- The HRUPAA can support data rates of a few Mbits/second to TDRS H,I,J, and hundreds of Mbits/second to a ground terminal.
- In 1997 GSFC awarded Harris Corporation a $7 M cost-plus contract to provide an Engineering Model (EM) antenna.
- The EM antenna is suitable for ground based testing and demonstration of the technology, and has been tested in the Goddard Electro-magnetic Anechoic Chamber and Near Field Antenna Measurement Lab.
- The technology is now ready for a flight project to fund construction of a space qualified HRUPAA for an operational demonstration.

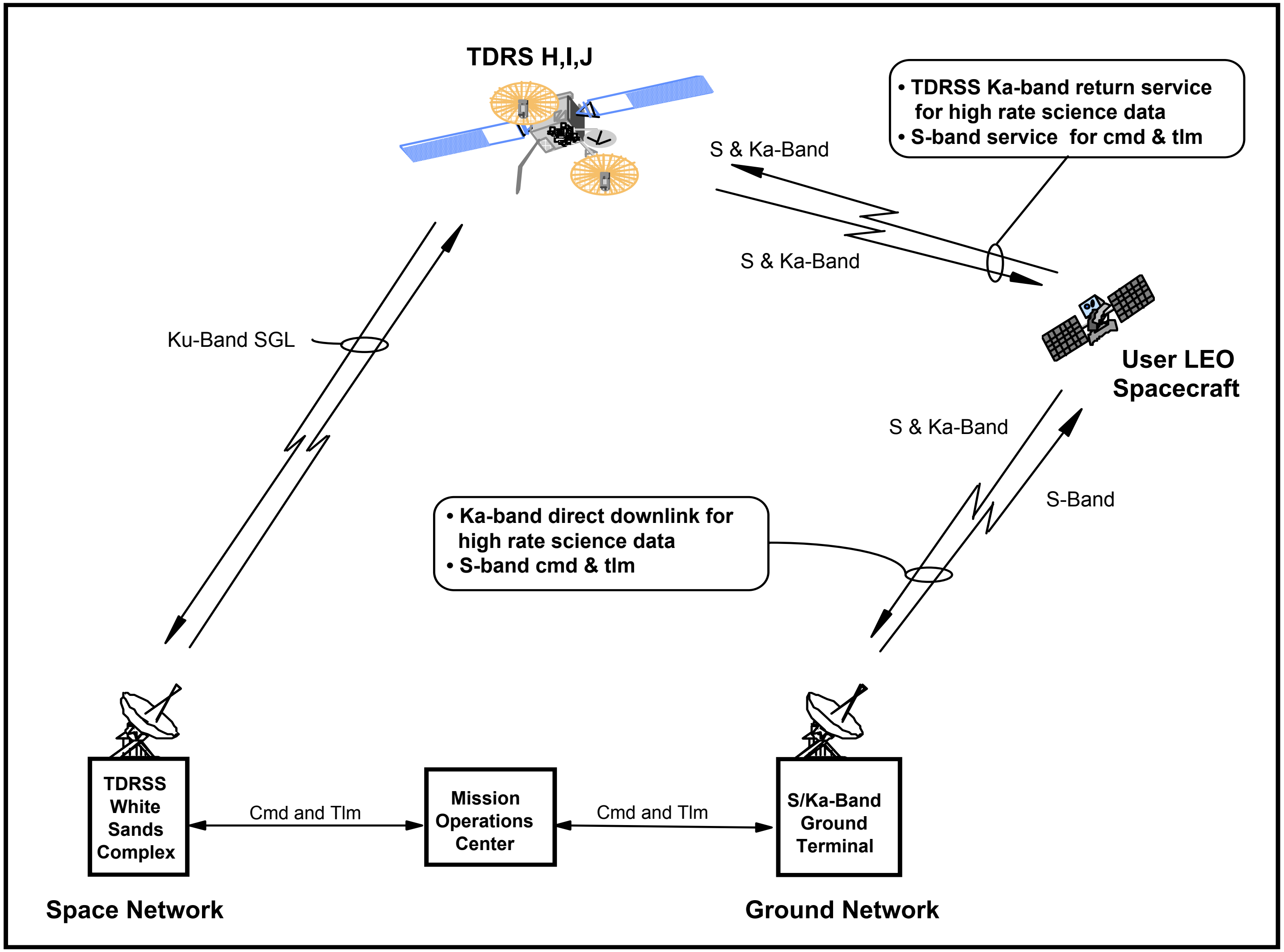
HRUPAA Performance Summary

- 25.25 GHz to 27.50 GHz
- ±60 degree scan
- ~ 5.2 kg mass
- 2 dB system compression
- <12 dB sidelobes
- 750 km orbit
- 33 dBW EIRP
- ~82 W power consumption
- LHCP, 11 dB cross-polarization isolation
- 55° C operational interface temperature
- ≤ 50 W dissipated to spacecraft
- 1773 Fiber Optic Command / Control Interface





NASA Space Network (SN) and Ground Network (GN) Reference Architecture

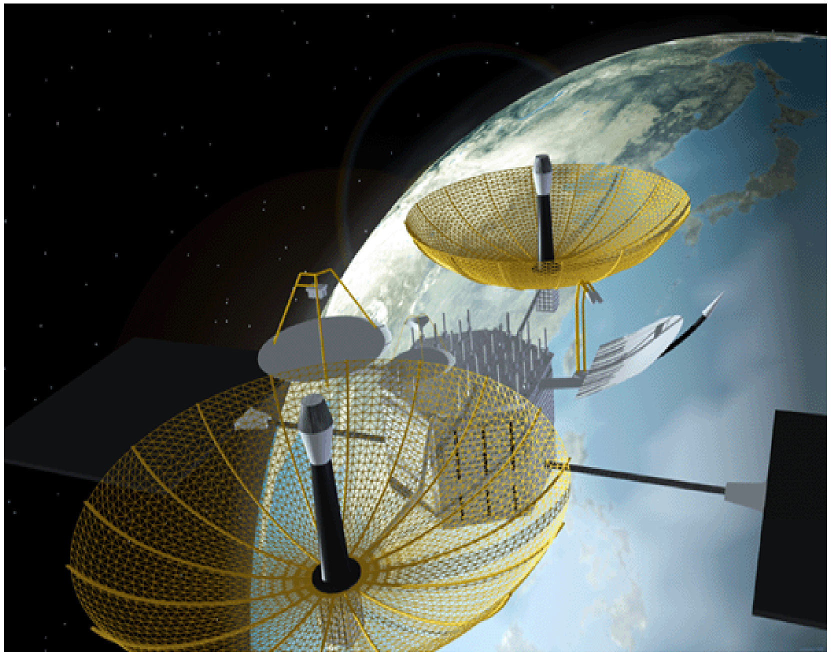


SN and GN Background

- NASA's Ka-band allocation will support space-to-space and space to ground communications for high rate Earth exploration satellite service
  - Space Network (space-space): 25.25 GHz - 27.5 GHz
  - Ground Network (space-ground): 25.5 GHz - 27.0 GHz
- NASA has made investments in Ka-band with TDRS H,I,J and associated technology developments
- However -
  - NASA's ground stations (WSC) that supports TDRS H,I,J are not capable of supporting the 650 MHz-wide Ka-band channel. Currently the SN provides support at S-band and Ku-band.
  - NASA's ground network is currently not Ka-band capable in the allocated frequency band. Currently the GN provides support just at S-band and X-band via direct links to ground stations located worldwide.

Ka-Band Transition Project

- In early 2000, NASA/GSFC initiated the Ka-Band Transition Project (KaTP) as a first step in transitioning the SN and GN to Ka-band operations:
  - Develop a new SN high rate telemetry service using the TDRS H,I,J 650 MHz-wide channel.
  - Develop a GN ground station to demonstrate direct-to-earth Ka-Band operations.
  - Provide a test bed within the SN and GN to demonstrate new communications technologies, including high data rate demonstrations (up to 1.2 Gbits/second).

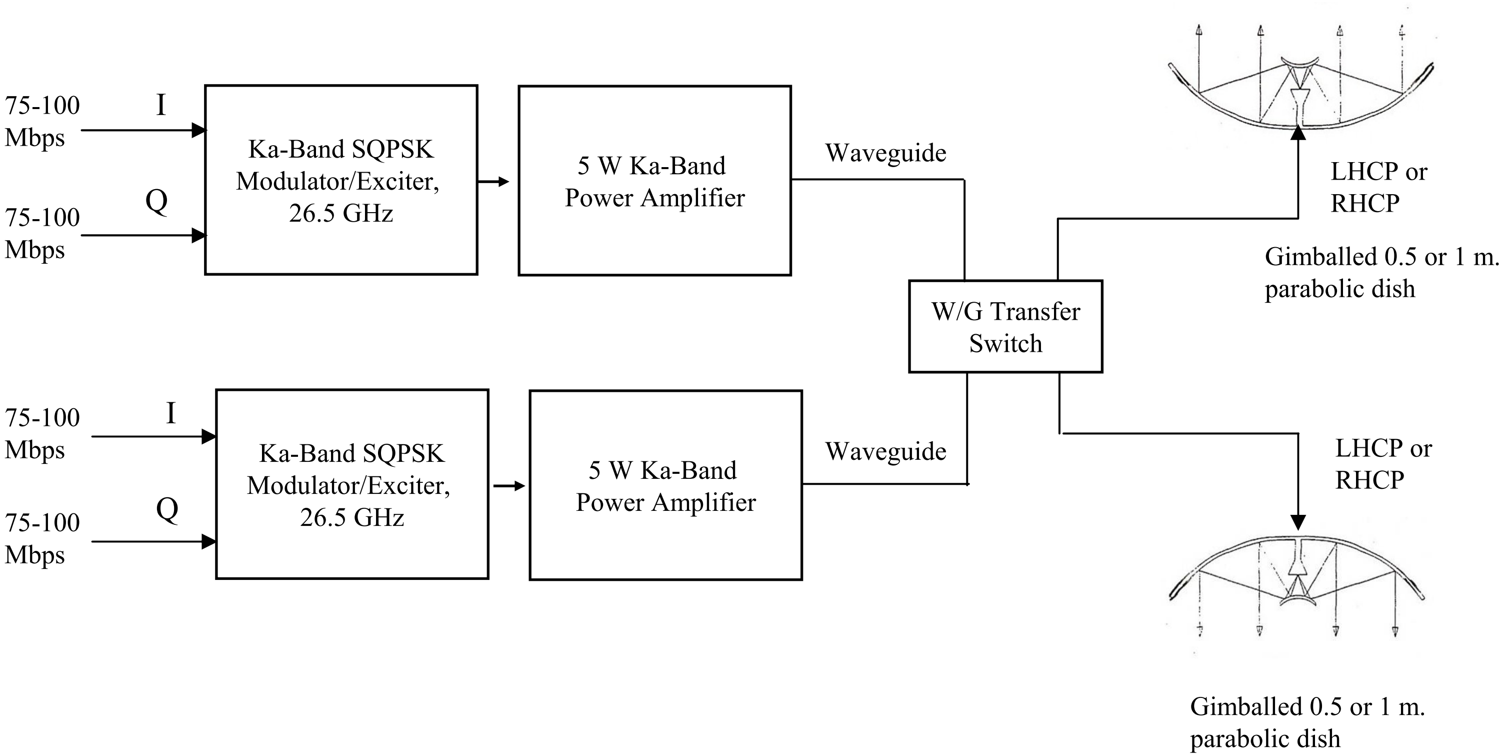


KaTP High Data Rate Demonstration

- KaTP high data rate demonstration will:
  - Characterize the performance of the physical return links at rates up to 1.2 Gbits/second
    - GN: Direct-to-earth Ka-band downlink
    - SN: return Ka-band link relayed via TDRS H
  - Characterize the acquisition and tracking performance of the GN Ka-band antenna.
  - Assess the effects of hardware distortion on the overall link.
  - Characterize the GN and SN system designs.
  - Provide an end-to-end system (i.e., “reference link” or test system) to help characterize new high rate Ka-band hardware.
- The demonstrations will assess the RF link performance via measurements of bit error rate and the signal spectra.
- A SN demonstration of 650 Mbits/second was completed in 2002.

Ka-Band Downlink for the Solar Dynamics Observatory

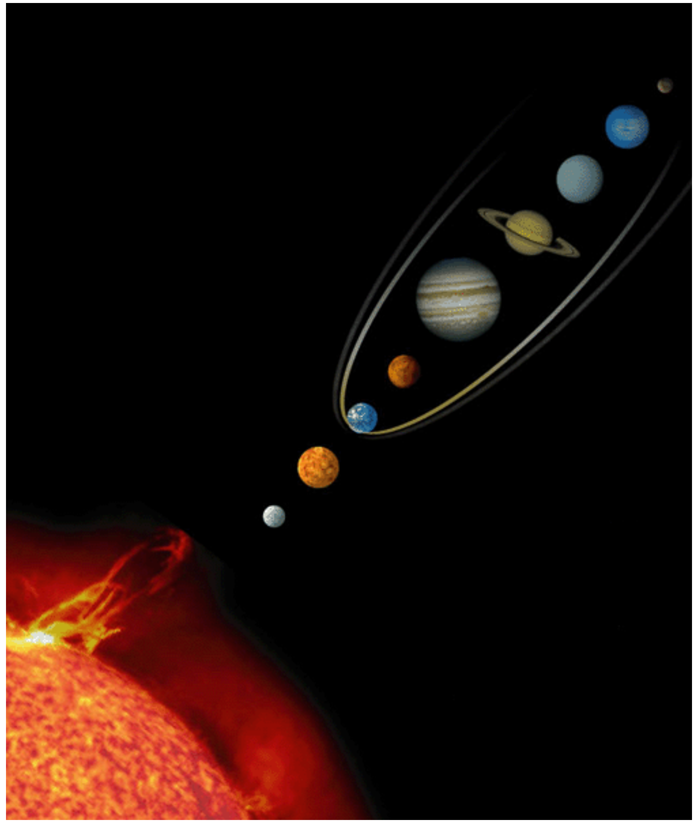
- Mission Goal: Observe the Sun's dynamics to increase understanding of the nature and sources of solar variability. Launch scheduled for 2007.
- In-house developed Ka-Band downlink will support continuous 150 Mbits/second from GEO (rate ½, K=7 conv and RS encoding).
- Spherical antenna coverage (dual gimballed HGAs).
- SDO RF System Block Diagram:



Preliminary SDO Ka Band Downlink Calculation

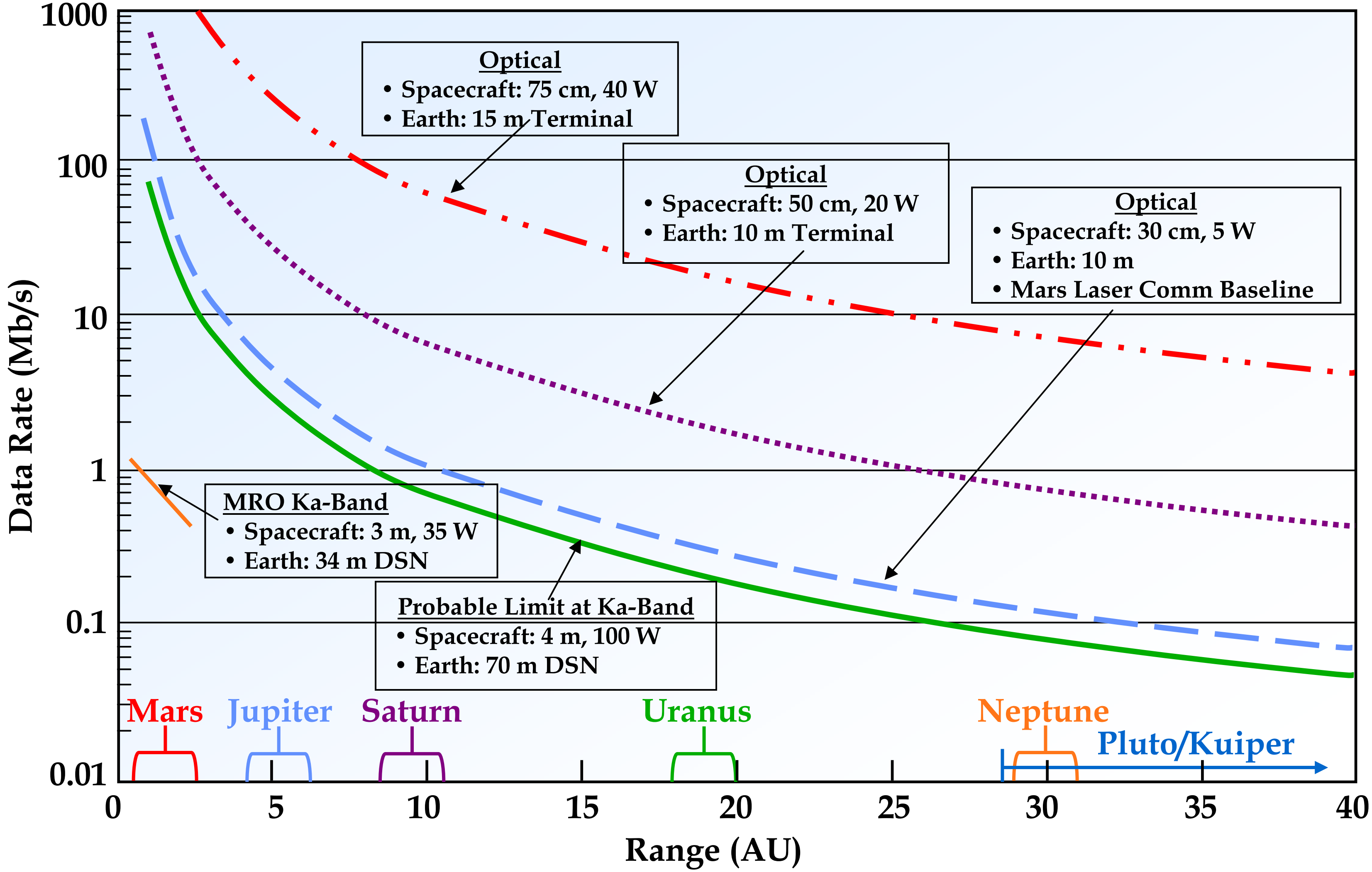
SPACECRAFT RETURN LINK			
	Data Rate (kbps)	150000.0	
	Carrier Frequency (MHz)	26500.0	
	Xmitter Power (Watts)	5.0	
	Xmitter Power (dBm)	37.0	
	Passive Loss (dB)	-3.0	
	Xmit Ant Gain (dB)	40.0	*0.5 m. dish*
	EIRP (dBm)	74.0	
TRANSMISSION MEDIUM			
	Range (km)	38691.3	
	Propagation Loss (dB)	-212.7	
	Atmospheric Atten (dB)	-2.5	
	Rain Atten (dB)	-5.0	*~99.6% availability at Goldstone*
	User Pointing Loss (dB)	-0.5	*0.5 degree pointing for s/c dish, 0.03 deg pointing for ground antenna*
	User Polarization Loss (dB)	-0.50	
	Total Space Path Loss (dB)	-221.2	
USER-GND SYST CHARACTERISTICS			
	Gnd Ant Diameter (ft)	30.50	*9.33 meter dish*
	Antenna Efficiency	0.60	
	Gnd Ant Gain (dB)	66.0	
	Received Pwr (dBm)	-81.2	
	System Noise Temp (K)	360.0	*3 dB NF=288.6*
	System G/T (dB/K)	40.5	
	Implementation Loss (dB)	-3.0	*Receiver loss, I/Q pwr. split, data imperfections, etc.*
	Received SNR - Eb/No (dB)	7.1	
	Req'd Eb/No for 1E-5 BER (dB)	3.6	*Rate 1/2, K=7 Conv., R/S coding*
	Signal Margin (dB)	3.5	

NASA has an ever increasing needs to move more and more data from farther and farther distances.



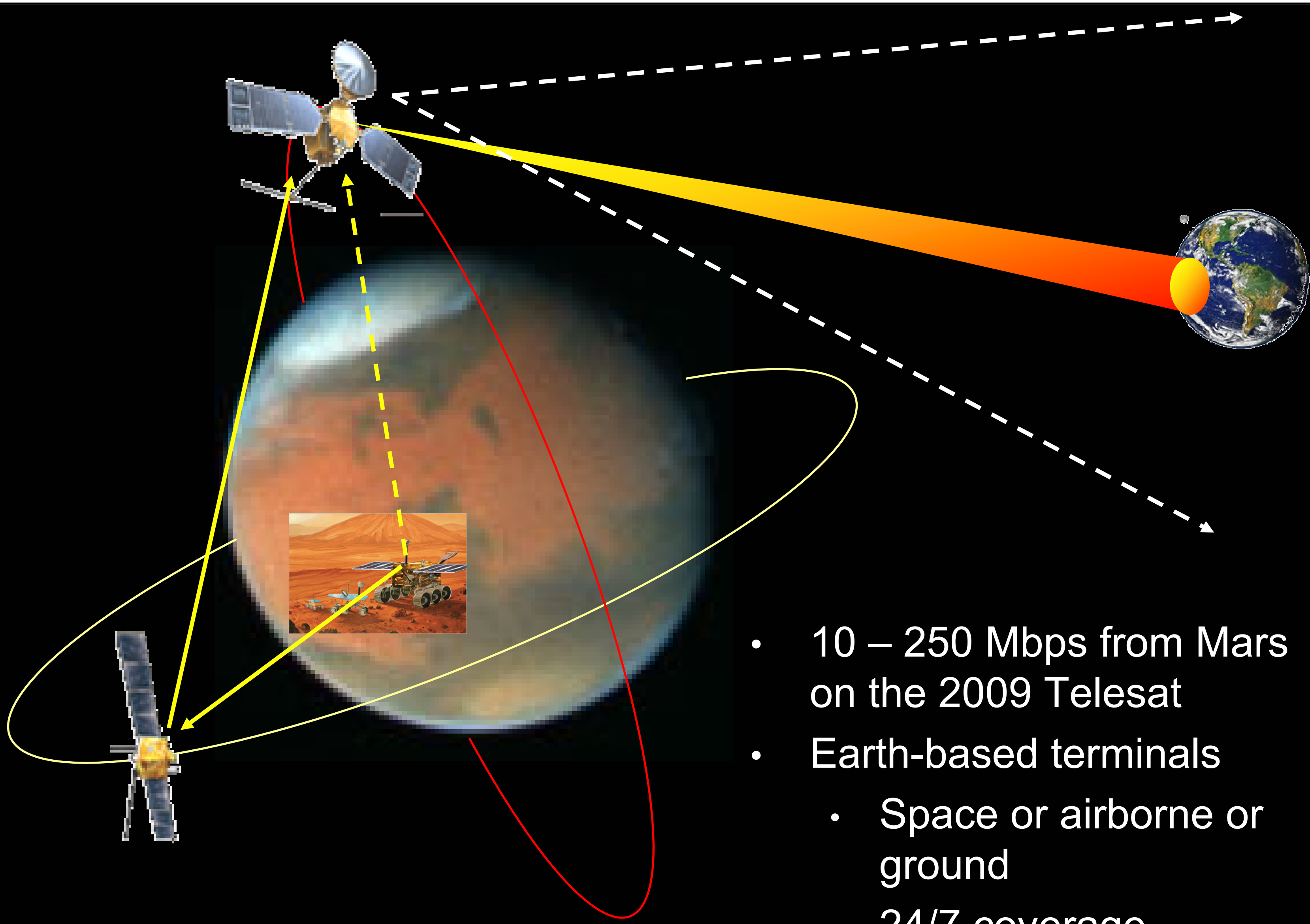
Laser Communications is one possible solution for very wideband downlink in the near future for both Near Earth and Deep Space Missions

The Potential of Laser Communications for Deep Space Missions



Note: 70 Meter Ka-Band DSN does not yet exist.

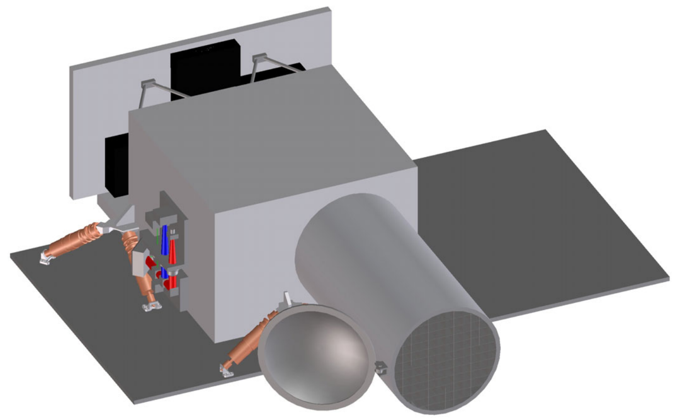
Mars LaserComm Experiment



- 10 – 250 Mbps from Mars on the 2009 Telesat
- Earth-based terminals
  - Space or airborne or ground
  - 24/7 coverage

The Strawman Laser Terminal at Mars

- Still performing engineering trades on whether the system should rely on a beacon from Earth or an integrated celestial sensor



STRAWMAN Features:

- Single module contains all subassemblies
- Should work within 2 degrees of the Sun
- Telescope Aperture Diameter: 30.5 cm
- Total mass: ~45 kg
- Average Power Consumption: ~110 Watts
- Peak Power Consumption: ~150 Watts
- Data rate: 10 – 250 Mbits/second
- Pulse Position Modulation
- Pointing scheme:
  - Coarse: Rely on the telesat for 1 mradian
  - Fine: Either a beacon from the ground or an integrated celestial sensor onboard the spacecraft

Goddard Space Flight Center

MIT Lincoln Laboratory

Jet Propulsion Laboratory

Conclusion

- Code 567 is developing technologies to increase the downlink data rates for future NASA missions.
- Most technology development efforts are either generic communications technology or concentrated on Ka-Band. Depending on the specific mission requirements, some technology is available today.
- The branch is also investigating Laser Communications for both near Earth and Deep Space high data rate missions to be launched by the end of the decade.